MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

ENT3056 – ADVANCED FABRICATION TECHNOLOGY

(NE)

13 MARCH 2018
2.30 p.m. - 4.30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages with 4 Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

4. Please refer to APPENDIX at page 7 and 8 for a list of physical constants, a list of formulas, and the error function table.

QUESTION 1

(a) Describe the principle of the Czochralski (CZ) process in the growth of silicon (Si) crystal with schematic illustrations. [2+9 marks]

(b) A boule of Si crystal is pulled from the melt, which is contained in a crucible of a CZ crystal puller. The melt is composed of pure silicon and phosphorus (P) dopant. After the pulling process the Si boule is sliced into thin sheet of wafers. The wafer taken from the top of the Si boule has a doping concentration of 5×10^{14} cm^{-3}. The segregation coefficient (k) for P dopant is given as 0.35. Determine the doping concentration of the wafer taken from the position corresponding to 55% of the initial charge solidified. [4 marks]

(c) Identify a physical vapor deposition (PVD) system which enables the growth of metal and metal oxide films with good conservation of material composition, step coverage, and film adhesion. Sketch the system and label the constituting parts in the system. Describe the working principles of the PVD system. [4+6 marks]

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QUESTION 2

(a) Describe the difference in doping mechanisms between the thermal diffusion and ion implantation processes. Explain why ion implantation is preferred over diffusion technique in the high-density circuits which require smaller feature sizes and closer spacing of the circuit components. [9 marks]

(b) Describe the impact of increasing doping concentration on the conductivity of the semiconductor film. Discuss the role of degenerate semiconductors in the metallization scheme for the integrated circuits. [4 marks]

(c) In an ion implantation process, boron (B) dopants are implanted into a silicon substrate to form a P-Well region. The projected range of the implanted dopant profile is 1500 Å. Take the standard deviation of the projected range as 450 Å. Given an implantation dose of 10^{10} cm^{-2}, determine the depth of the peak of the implanted profile, and the peak concentration of the B dopant. [4 marks]

(d) An n-type silicon wafer has a uniform background concentration of 1.98×10^{18} cm^{-3}. A boron (B) pre-deposition is performed at 800 °C for 40 minutes. The B concentration at the surface is 3×10^{19} cm^{-3}. The diffusion coefficient for B at 800 °C is given as 1×10^{-14} cm^2s^{-1}. Determine the junction depth following the B pre-deposition process. Refer to page 8 for the error function table. [8 marks]

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QUESTION 3

(a) In photolithography, there are three printing methods, namely contact, proximity and projection printing methods.

(i) Sketch the contact and proximity printing methods with labels. Describe **ONE (1)** advantage and disadvantage of these two printing methods, respectively. [6 marks]

(ii) A photolithography system uses an Excimer laser (ArF) light source with a deep-ultraviolet (DUV) wavelength of 193 nm. If the photoresist thickness is 1.5 μm and the photoresist constant, k, is given as 0.85, determine the minimum feature size, W_{min}, that can be achieved using the contact printing method, and the proximity printing method with an air gap of 35 μm, respectively. [4 marks]

(b) Figure 3(b) demonstrates the ultraviolet (UV) exposure of the photoresist through the chrome pattern on the mask. Illustrate the final structure after the development process, for **positive** and **negative** photoresist, respectively.

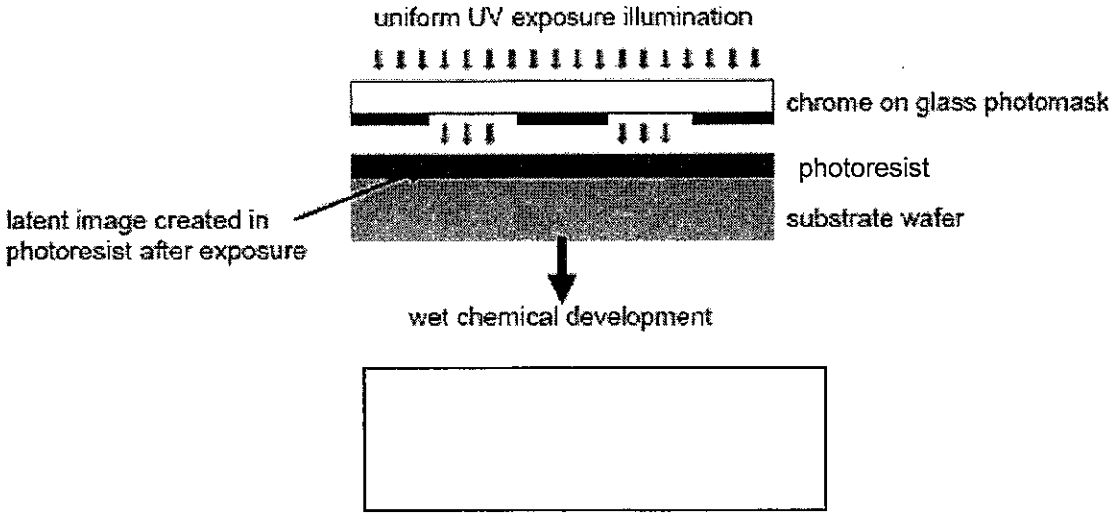

Figure 3(b)

[2+2 marks]

Continued .....

QUESTION 3

(c) The cross-sectional view of a field effect thin film transistor (TFT) is given in Figure 3(c). The TFT constitutes of aluminum metal layers as control gate and drain/source metal electrodes, semiconductor as channel layer, and silicon dioxide (SiO_2) as gate insulator layer, on an insulating substrate.

(i) Design the fabrication process for the TFT by sketching the cross-sectional structure upon each of the process step. Label the structures, state the processes, and indicate both the mask patterns and type of resist clearly. [10 marks]

(ii) Identify the number of mask required in the patterning of the TFT. [1 mark]

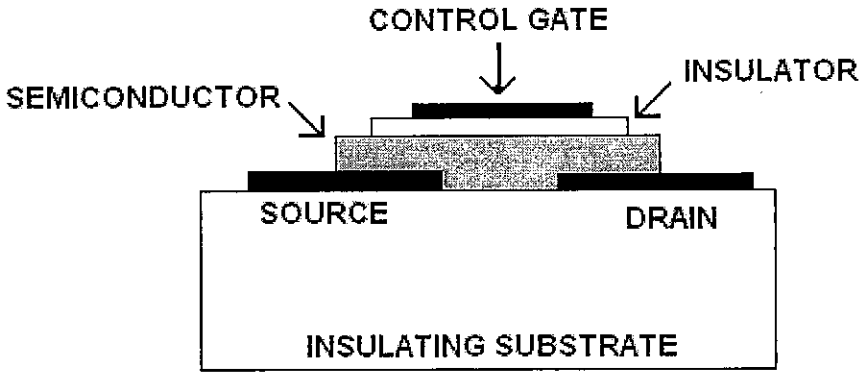

Figure 3(c): Schematic cross-section of a TFT.

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QUESTION 4

(a) Describe the advantages and disadvantages of the copper (Cu) metallization as compared to aluminum (Al) metallization for the interconnection scheme of ultra large scale integrated (ULSI) technology. [4 marks]

(b) Suggest a solution to address the issue arises with using Cu as candidate for metallization in ULSI. Give **TWO (2)** example on proposed solution. [4 marks]

(c) In metallization scheme describe the effects of the voids and pileups (hillocks) on the reliability issue of the metal liners in interconnect scheme. [4 marks]

(d) What is the difference between an Ohmic contact and a Schottky contact? [4 marks]

(e) In one metallization scheme the Al metal liner is deposited on top of the silicon dioxide (SiO_2). If Al is replaced with Cu metal liner, and SiO_2 is replaced by one of the low-k dielectric materials, estimate the percentage of reduction in the resistance-capacitance (R-C) time constant delay. The resistivity of Al and Cu is given as 2.7 μohm-cm and 1.7 μohm-cm, respectively, whereas the dielectric constant (k) for the SiO_2 and the low-k dielectric material is 3.9 and 2.2, respectively. [3 marks]

(f) Determine the thickness for a tungsten silicide film with a measured sheet resistance of 0.8 ohm/□. Given that the film resistivity is 20 μohm-cm. [2 marks]

(g) The area for a Cu contact on silicon substrate is given by 5 μm by 5 μm. What is the maximum current permissible to flow in this Cu contact if the maximum current density can only be 3.5×10^5 A/cm^2? [4 marks]

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APPENDIX (Physical Constants):

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, k = 1.380622×10^{-23} J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, e = 1.60219×10^{-19} C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 Cs^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^4 G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$X_j = R_P \pm \Delta R_P \sqrt{2\ln(N_P/N_B)}$	$N(x) = \frac{Q_o}{\sqrt{2\pi}\Delta R_p} e^{\left[-\frac{1}{2}\left(\frac{x-R_p}{\Delta R_p}\right)^2\right]}$
$x_j = 2\sqrt{Dt\ \ln(N_0/N_B)}$	$N(x,y) = \frac{N(x)}{\sqrt{2\pi}\Delta R_\perp} e^{\left[-\frac{y^2}{2\Delta R_\perp{}^2}\right]}$
$x_j = 2\sqrt{Dt}\ erfc^{-1}(N_B/N_o)$	$C_s = \frac{Q}{\sqrt{\pi Dt}}$
$RC = \frac{R_s L^2 \in_{gd}}{d_{gd}} = \frac{\rho}{d_{poly-si}} \frac{L^2 \in_{gd}}{d_{gd}}$	$Q = 2C_s\sqrt{\frac{Dt}{\pi}}$
$C(x,t) = C_s erfc\left[\frac{x}{2\sqrt{Dt}}\right]$	$Q = \sqrt{2\pi} N_p \Delta R_p$
$C(x) = \frac{Q}{\sqrt{\pi Dt}} e^{-\left(\frac{x}{2\sqrt{Dt}}\right)^2}$	$C = k\,C_0\,(1-x)^{k-1}$
$W_{min} = k\{\lambda/NA\}$	$W_{min} = \sqrt{k\lambda g}$
$R_c = \rho_c/A, \qquad \rho = Rs\cdot t$	$k_0 = \frac{C_s}{C_l}$

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Values of the error function $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\operatorname{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi}\, t} \exp(-t^2)$

erfc (t) = 1 - erf (t)

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